Idaho National Engineering and Environmental Laboratory

Development of a High Temperature Solid Oxide Electrolyser System

Steve Herring, Ray Anderson, Jim O'Brien, Paul Lessing, and Carl Stoots

2003 Hydrogen and Fuel Cells Merit Review Meeting

Berkeley, CA, May 20, 2003

1. Relevance/Objective

OHFCIT: Production Goals

Research and develop high and ultra-high temperature processes to produce hydrogen through chemical cycle-water splitting technology or other non-carbon-emitting technology utilizing heat from nuclear or solar sources.

Table 4.1.7b. Technical Targets: High Temperature Solid Oxide Water Electrolysis[1]

Characteristics		Units	2003 Status	2005 Target	2010 Target
Cell Stack	Cost	$/kg	0.64	0.46	0.27
	Efficiency[2]	%	76	85	94
Balance of Plant	Cost	$/kg	0.83	0.52	0.32
	Efficiency	%	92	93	96
Electricity[3]	Cost	$/kg	1.59	1.41	1.23
Heat[4]	Cost	$/kg	0.19	0.17	0.15
Total	Cost[5]	$/kg	3.25	2.55	1.96
	Efficiency	%	70	79	90

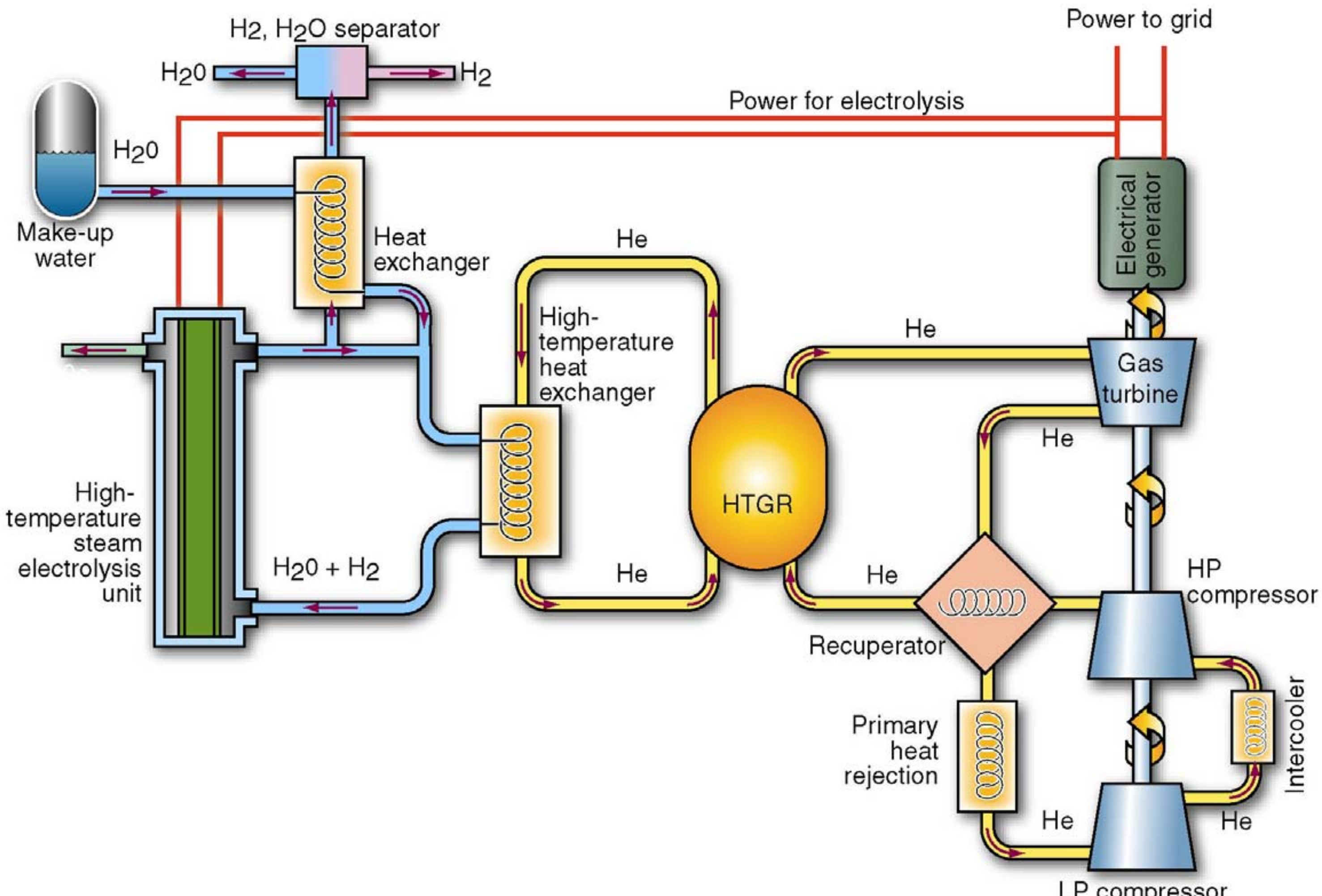
[1] Electrolyser delivering 500 kg per day (based on projected technology developments, not current system sizes).
[2] Based on total energy into electrolyzer. All calculations based on Lower Heating Value of hydrogen.
[3] Assumes electricity at $0.045 per kWh and 95% capacity factor.
[4] Heat is valued at $0.016 per kWht.
[5] Based on system capital cost of $1500, $1100, and $700. Includes O&M cost at 2% of capital charges, 15% IRR, 20 year equipment life.

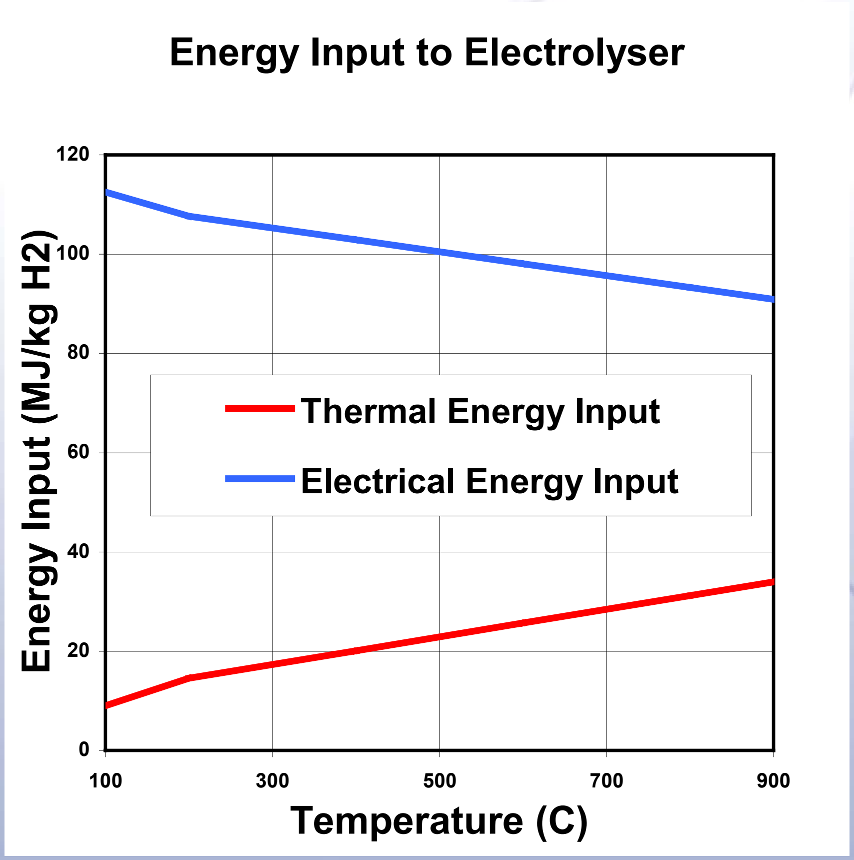
Barriers: U (scaling), V (renewable integration), W (electricity costs)

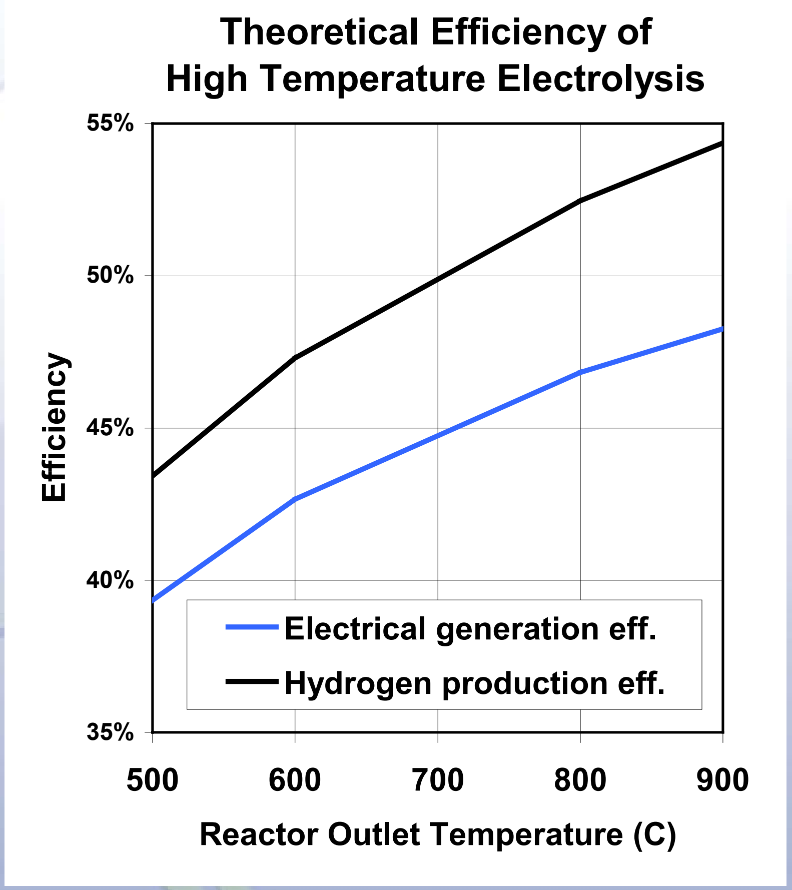
2. Approach

- Development of energy-efficient, high-temperature, regenerative, solid-oxide electrolyser cells (SOECs) for hydrogen production from steam.
  - Reduce ohmic losses to improve energy efficiency
  - increase SOEC durability and sealing with regard to thermal cycles
  - minimize electrolyte thickness
  - improve material durability in a hydrogen/oxygen/steam environment
  - Develop and test integrated SOEC stacks operating in the electrolysis mode
- Specification and testing of hydrogen-permeation-resistant materials for a high-temperature heat exchanger

2. Approach: High Temperature Electrolysis System





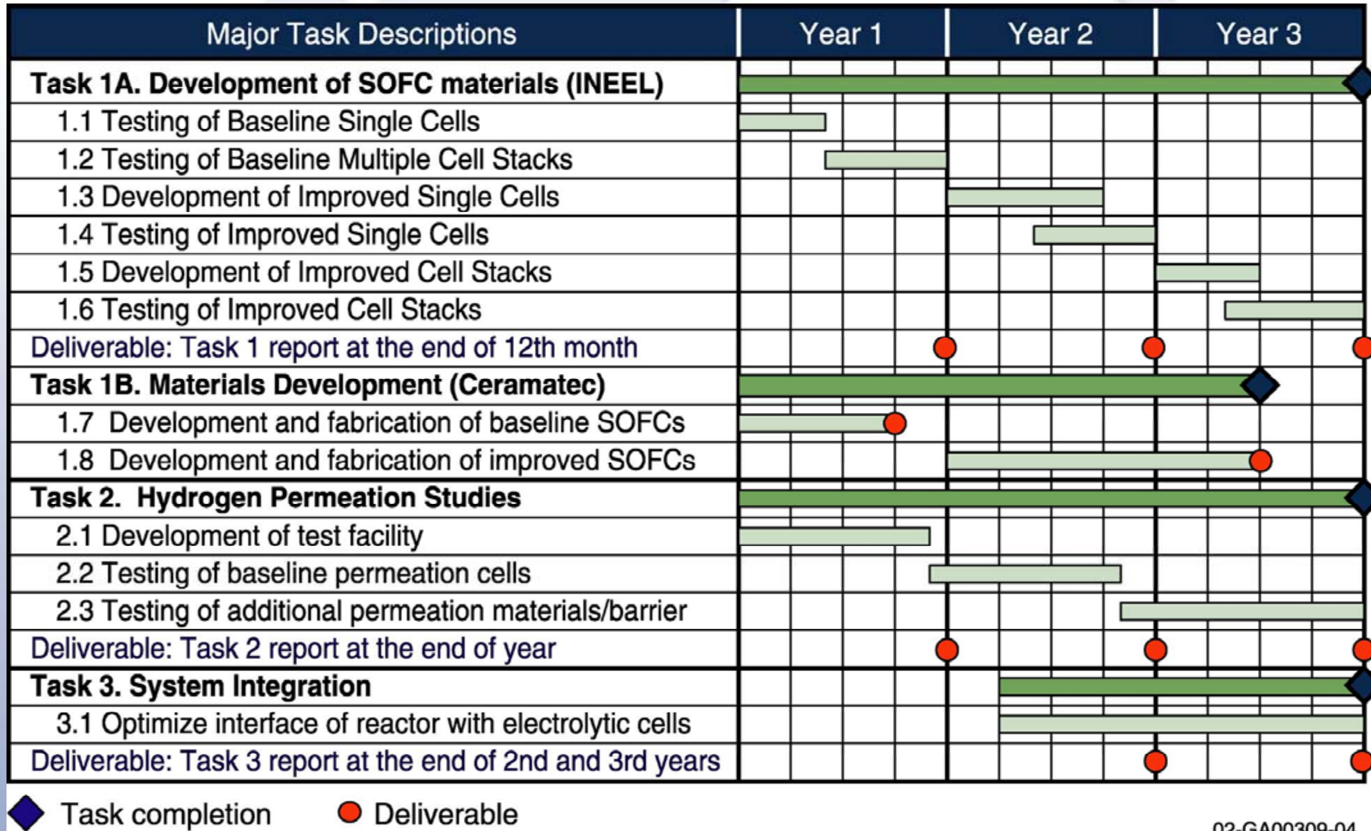


Sulfur-Iodine efficiency estimates:

0% at 670 C peak
10% at 700 C peak
35% at 800 C peak
42% at 830 C peak

3. Project Timeline / 6. Plans, future milestones

Began Jan. 2003



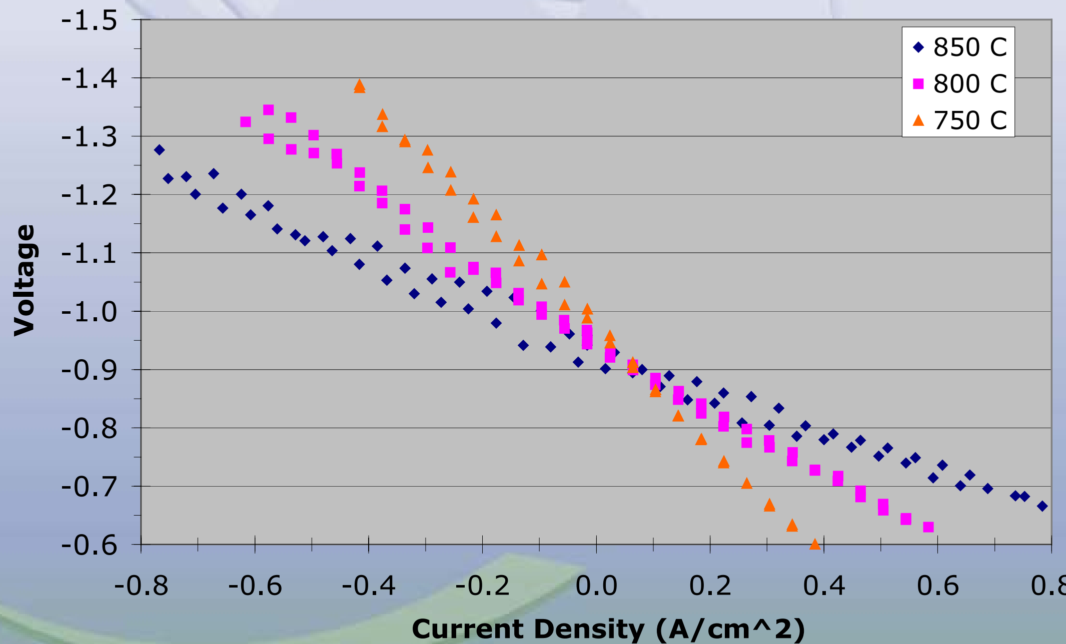
4. Accomplishments/Progress

- ***Funding began Jan. 21, 2003***
- ***Subcontract placed with Ceramatec***
- ***Initial single cell received for testing at INEEL***
- ***Tests conducted at Ceramatec***
- ***Test loop designed, passed safety review and constructed***
- ***Initial INEEL testing, May 14, 2003***

Initial Data from Ceramatec

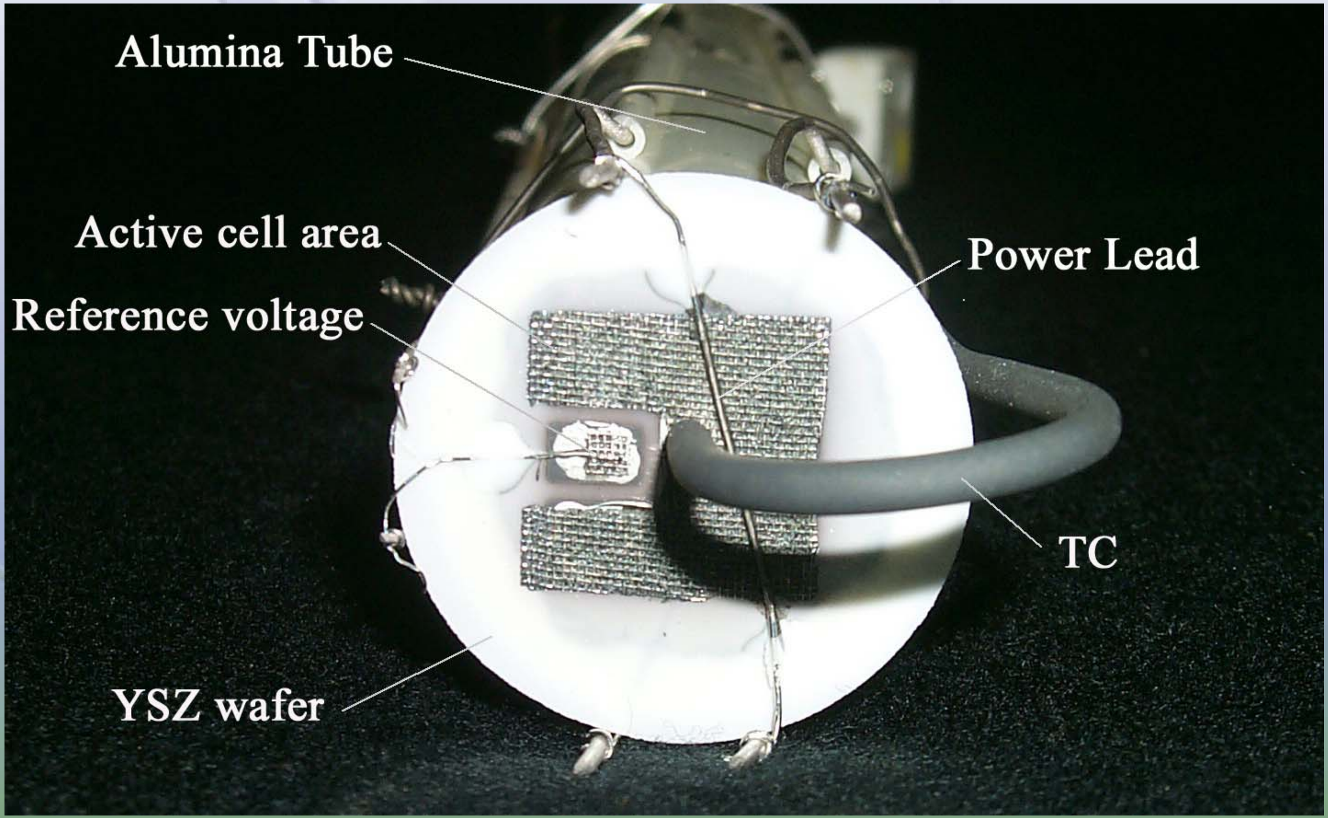
Electrolysis portion:
ASR: 0.45 ohm-cm^2 at 850 C
0.63 at 800 C, and 0.98 at 750 C.
Bubbler temperature: 88 C
OCV: 0.94 V at 800 C
Input: 50:50 mixture steam and H2
H2 flow: 35 sccm
cell area: 2.5 cm^2
Exit mole fraction is calculated to have 73% H2 and 27% H2O using the 850 C peak current value.

Reversible SOFC Electrolysis

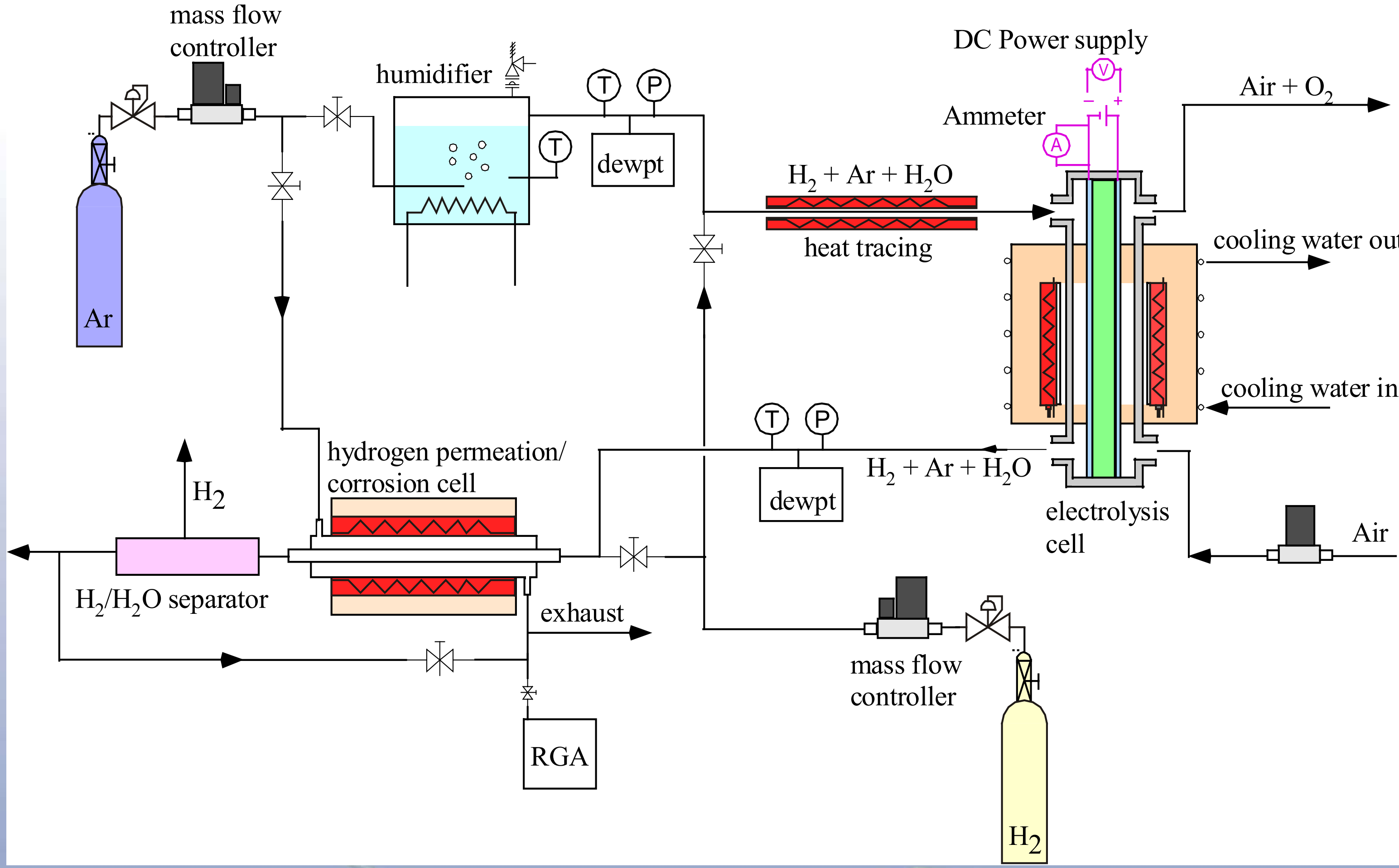


Ceramatec "button cell" for initial single-cell testing:

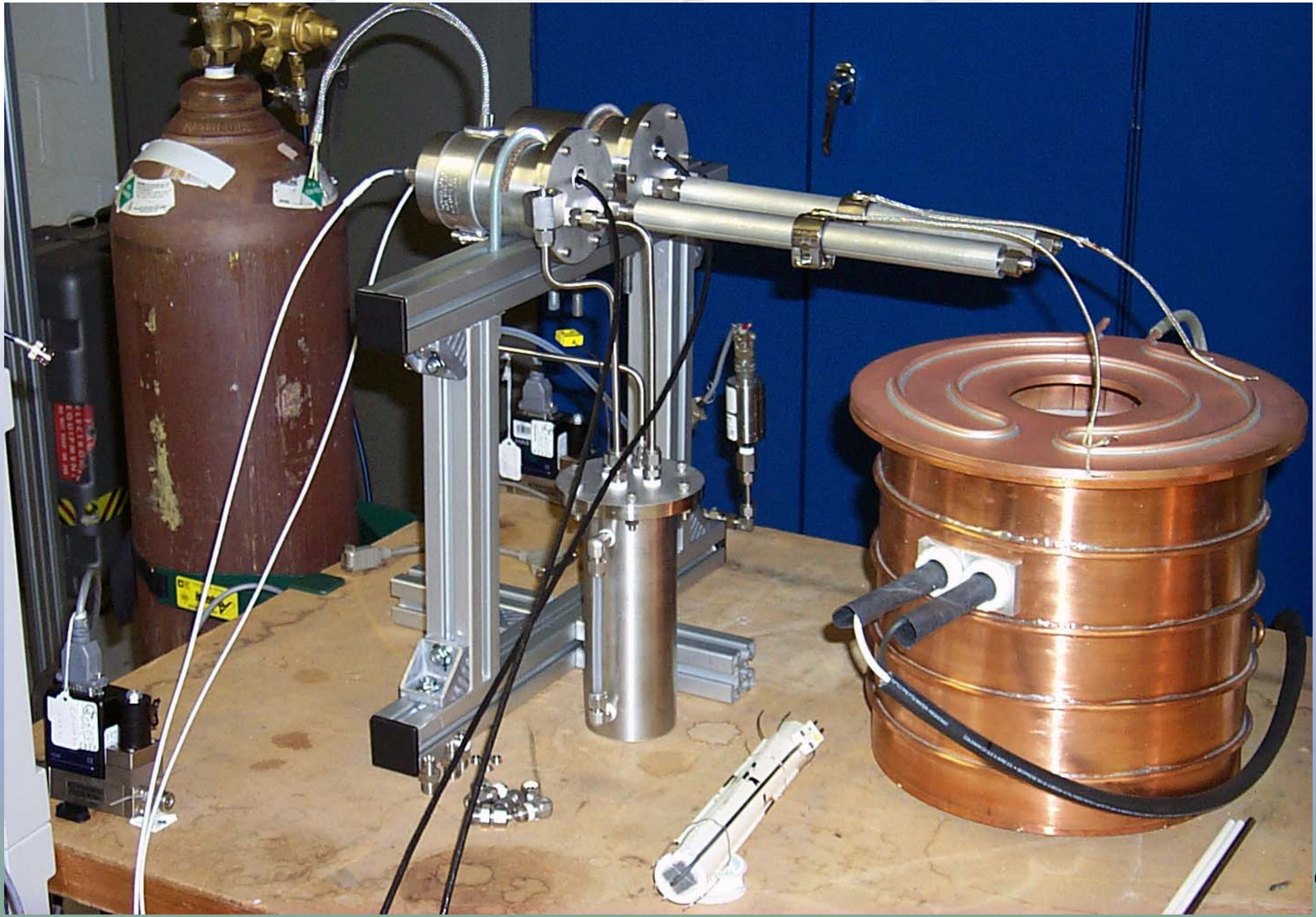
- Anode: Nickel zirconia cermet (cathode in electrolysis mode)
- Cathode: Strontium-doped lanthanum manganite (anode)
- Electrolyte: YSZ, 175 μm thickness
- Active cell area: ~ 3.2 cm^2
- Includes an electrically isolated electrode patch for monitoring of reference open-cell voltage



INEEL High-Temperature Steam Electrolysis and Hydrogen Permeation Experiment



Experimental Hardware in Assembly at INEEL



5. Significant interactions with industry

Industrial Collaborator

Ceramatec, Inc.

Salt Lake City, UT

- 25+ years of contract R&D experience developing electrochemical ceramics

Responsibilities:

- Fabricate single-cell SOECs and planar cell stacks for testing at INEEL
- Collaborate in testing SOECs for High Temperature Electrolysis (HTE)
- Develop improved SOECs for the HTE application

Conclusions

- High-temperature steam electrolysis using a high temperature heat source is a viable near-term strategy for large-scale hydrogen production
- Solid-oxide cells represent a logical choice for high-temperature steam electrolysis due to their high operating temperature and high efficiency
- INEEL is initiating a research program to study materials and thermoelectric efficiency issues related to the HTE process using solid oxide electrolytes